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An updated inventory of the vascular flora of the Island of Montecristo (Tuscan Archipelago, Italy)

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Abstract

We present an updated inventory of the vascular flora of the island of Montecristo (Tuscan Archipelago, Italy). The inventory has been updated based on a comprehensive bibliographical revision of floristic floras and previous inventories, together with the revision of herbarium specimens already preserved in Tuscan Herbaria and the implementation of survey campaigns carried out on the island between 2011 and 2024. The inventory counts 582 specific and subspecific taxa currently present on the island (including 515 spontaneous taxa and 67 cultivated ones), the highest number of species ever recorded on the island. Since 2000, 45 new to Montecristo Island, and 28 species confirmed after one century. We excluded 14 species, 8 of which were the result of a revision of herbarium material, which led to the correction of previous erroneous identification or due to the description of new taxa, such as *Saxifraga montis-christi* Mannocci, Ferretti, Mazzoncini & Viciani. The characterisation of the flora of Montecristo is consistent with the Mediterranean climate of the island in terms of life forms and chorotypes. The analysis showed that the main geographical distribution elements are Eurosiberian-Mediterranean and Mediterranean species, while the predominant life form is the therophyte. From a floristic point of view within the Tuscan Archipelago, Montecristo is the poorest island in terms of species and has the highest amount of endemism in relation to its surface area.

Keywords

Alien plant species, biodiversity, endemics, floristic studies, Mediterranean island, taxonomy

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Introduction

The production of easily accessible plant species lists, such as databases and floristic inventories, is fundamental to knowing and quantifying plant biodiversity (Kier et al. 2005). Floristic inventories contain fundamental information on the ecology of a geographical area and could also be important in ensuring and managing the conservation of the biodiversity of the studied site (Mayer 2016; Peruzzi 2018). Particularly, the Mediterranean is a hotspot of diversity, including thousands of islands and islets (Brundu et al. 2013) that are home to a high rate of endemic plant species (50–59%: Médail and Quézel 1997; Médail 2013) and vulnerable species that are worthy of conservation (Foggi et al. 2015). The archipelagos of the Mediterranean are therefore important examples of circumscribed geographical areas where knowledge of biodiversity needs to be increased and deepened to preserve their biological values (Valavanidis and Vlachogianni 2011). The Tuscan Archipelago consists of seven islands and several islets, all with a significant naturalistic value and richness (Arrigoni et al. 2003). The Archipelago has been the subject of historical and intensive interest, accumulating a substantial quantity of botanical data. This begins with Sommier's work at the beginning of the last century and continues to the present day. This data allows us to trace changes in the archipelago's flora until the most recent socio-economic changes after the Second World War. These changes have significantly increased anthropogenic pressure on the islands, leading to modifications in their landscape and vegetal composition (Chiarucci et al. 2017). In recent decades, the Tuscan Archipelago's landscape has changed due to rapid socio-economic dynamics that have shifted from agro-pastoral land use to a more tourism-industrial approach (Carta et al. 2018). This change in land use enhanced anthropogenic direct and indirect impacts on insular biotas, and local floristic shift, e.g. caused by an increase of alien species (Lazzaro et al. 2014). These impacts are exacerbated by the insularity of these areas, with a highly concentrated sample of natural features that are more vulnerable than those on the mainland (Drake 2002). This study presents an updated list of the spontaneous and cultivated vascular plants occurring on Montecristo, one of the seven major islands of the Tuscan Archipelago. Montecristo is among the least-known islands of the Archipelago from a botanical point of view due to its location, history, and morphological characteristics that have not facilitated its exploration. From a geobotanical perspective, Montecristo Island is situated in the western Mediterranean vegetation zone. The island is largely devoid of vegetation, with a discontinuous cover consisting mainly of cryptogamic vegetation. Notably, mosses and lichens are abundant, covering almost all the rocky outcrops and scrub. Although there are some scattered trees, there are no true tree formations. Approximately 200 scattered and relic holm oaks can be found across the island, particularly in the upper or mid-upper sections of the Collo dei Lecci and Collo Fondo valleys. These trees represent the remnants of an ancient holm oak forest (Crudele et al. 2005), with radiocarbon dating indicating a range of 430 to 742 years old (Filibeck et al. 2023). Montecristo occupies a distinctive position in the phytogeographical context, acting as a transition zone between the Mediterranean-western and central-east-

ern floristic elements (Arrigoni 1972). Indeed, the study of the floristic knowledge of the Tuscan Archipelago has also experienced a renewed interest recently, leading to the production of updated inventories (Carta et al. 2018) or dedicated contributions (Lazzaro et al. 2021). Although the last published flora for Montecristo dates back to 1976, studies of its vegetation have continued (Filibeck et al. 2023). Moreover, ongoing exploratory visits to the island (and other islands of the Tuscan archipelago) have led to the discovery of many new records and the confirmation of previously documented species (Peruzzi et al. 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2023).

This work aims to synthesise historical data, derived from the literature and herbarium specimens, with more recent data, largely unpublished, collected during the last ten years of exploration.

Materials and methods

Study area

The island of Montecristo (Tuscany, Italy) is situated in the Tyrrhenian Sea (42°19'N, 10°19'E), west of the Tuscan coast. The island of Montecristo has been subjected to a specific regime of protection, being an integral reserve of the former State Forestry Corp (now Comando Unità Forestale, Ambientale e Agroalimentare (CUFAA) of the Arma dei Carabinieri) in 1971, and it is currently included in the Tuscan Archipelago Park, which was established in 1996. Montecristo, formed by a magmatic intrusive body, has a surface extension of 10.4 km^2, is mainly mountainous and vaguely rectangular, divided in half asymmetrically by a mountainous ridge whose peaks are the Cima della Fortezza (645 m a.s.l.) and the Cima dei Lecci (563 m a.s.l.). The remarkable geological uniformity is reflected in the pedology of the island (Innocenti et al. 1997). Soils derived from granite are generally sandy and very poor in Ca and assimilable P, instead possessing high levels of alkaline bases (Mittempergher 1954), with a neutral-acid reaction (Crudele et al. 2005). The soils of Montecristo therefore appear homogeneous, superficial and poorly developed, due to the little organic substance that allows the formation of little humus, which is also affected by the island's high temperatures during the summer season (Paoli and Romagnoli 1976).

Vegetation

The vegetation of Montecristo is predominantly a degraded and uniform Mediterranean scrub. It consists of a tall and often impenetrable fragmentary form of *Erica arborea* L. and *Erica scoparia* L. subsp. *scoparia*. These are interspersed to varying degrees with a low shrub component dominated by *Salvia rosmarinus* Spenn., *Cistus monspeliensis* L., *Teucrium marum* L., *Helichrysum italicum* (Roth) G.Don and, more rarely, *Cistus salviifolius* L. The most extensive formations are under the Monte della Fortezza, above Cala S. Maria, Cala della Fortezza and Cala Maestra. The low shrub

with a dominance of *Cistus* forms an open garigue that tends to close in areas with a weak slope. The garigue in this area is characterised by shrubs of *Teucrium marum* and an underlying carpet of scattered grasses. This ecosystem is associated with the endemic steno-tirrenic *Carduus fasciculiflorus* Viv. In areas that are regularly affected by meteoric water inflow, temporary ponds are found. These ponds are characterized by the presence of endemic *Mentha requienii* Benth. subsp. *bistaminata* Mannocci & Falconcini, *Isoëtes durieui* Bory, and some species of annual rushes. Although relatively widespread, they are fragmented and spread over small areas. In the flat areas of the ridge, at the edges of shrub clusters, where outcropping rock prevents plant growth, there are thermophilic grasslands dominated by annual *Plantago* sp. pl. and *Tuberaria guttata* (L.) Fourr. The vegetation found on damp and shady cliffs is characterised by *Arenaria balearica* L. and *Cymbalaria aequitriloba* (Viv.) A.Chev. subsp. *aequitriloba*. The halophilous vegetation along the coastal strip develops in an extremely fragmented manner and is characterised by the presence of the endemic *Limonium sommierianum* (Fiori) Arrigoni. The island is home to endemic species such as *Saxifraga montis-christi* and *Hieracium racemosum* Waldst. & Kit. ex Willd. subsp. *amideii* Gottschl., Gonnelli & Zoccola, but also shares endemics like *Linaria capraria* Moris & De Not. and several other taxa found in western Mediterranean islands (Paoli 1975). The latter group includes Sardinian-Corsican and Sardinian-Balearic endemisms such as *Arenaria balearica*, *Arum pictum* L.f. subsp. *pictum*, *Carduus cephalantus* Viv., *Carduus fasciculiflorus*, *Cymbalaria aequitriloba*, *Mentha requienii* subsp. *bistaminata*, *Scrophularia trifoliata* L., *Verbascum conocarpum* Moris subsp. *conocarpum* (Peruzzi et al. 2014a). The ancient colonisation of the island was mainly of Sardinian-Corsican origin, as evidenced also by the distribution of plant species such as *Alkanna lutea* Moris, *Fumaria bicolor* Sommier, *Sedum andegavense* (DC.) Desv., and *Teucrium marum*, which have a mostly western Mediterranean gravitation (Arrigoni 1972).

Floristic inventories and literature search

A comprehensive bibliographic revision of floristic floras and inventories was conducted, along with the revision of specimens already preserved in the Tuscan Herbaria of Florence (FI) and Siena (SIENA) (international code according to Thiers 2020, and onwards) the examination of reports from various contributors, and the implementation of survey campaigns specifically designed for this study. The revision of the national floras included Fiori (1923–1929), Bertoloni (1833–1854), and Fiori and Béguinot (1909, 1910). Additionally, local floras were consulted, including Caruel (1860–1864), Caruel (1864), Béguinot (1901), Sommier (1902), and Briquet (1910). Furthermore, publications that might contain floristic data for Montecristo were considered, such as Toschi (1953). The initial contribution to the flora of Montecristo, ascribed to Giuseppe Giuli (1764–1842), could not be located in the Indicatore Sanese (Giuli 1833). The only extant volume was found to be lacking the pages enumerating the plants. However, the data, about 24 species he documented, were extrapolated from Bertoloni (1833–1854). The examined bibliographical data on Montecristo include Fabbri (1963, 1966); Paoli

and Romagnoli (1976); Paoli and Ciuffi Cellai (1976); Sartori (1978); Filipello and Sartori (1983); Viegi and Cela Renzoni (1981); Landi et al. (2008), as well as Peruzzi et al. (2011, 2012, 2014b, 2014c, 2015, 2016, 2017, 2018, 2019, 2023). The research, for taxa of any rank, was initially conducted using the following sources: Fiori and Paoletti (1902–1904); Fiori (1923–1929); Parlatore and Caruel (1848–1881); Arcangeli (1882–1894); Bertoloni (1833–1854); Baroni (1897); Caruel (1860–1864); Sommier (1902, 1903). Furthermore, for some authors, such as Sommier and Caruel, prominent botanists of the Tuscan Archipelago, the same search was conducted for any monographic contributions that might contain new taxa described for Montecristo Island. Examples of this include Sommier (1890, 1891, 1894, 1895, 1897, 1898, 1899, 1901, 1902, 1903, 1905, 1910, 1915). Following the literature review, survey campaigns were conducted on the island in 2016 and 2024. The subsequent identification of the samples collected during the field surveys, as well as samples collected from 2000 to the present day by the research group of the Department of Biology of the University of Florence, contributed to the expansion of the floristic knowledge of Montecristo.

Nomenclature

The data collected during the research may show inconsistent nomenclature. To update the nomenclature, we primarily used the directories available on the web, such as Portal to the Flora of Italy 2024.2 (https://dryades.units.it/floritaly/), which derives from Checklists of the native and alien floras of Italy (Bartolucci et al. 2024; Galasso et al. 2024), and their most recent updates (Bartolucci et al. 2024b; Galasso et al. 2024b). When we could not verify the correctness of the nomenclature with this database, we used The International Plant Names Index (IPNI; http://www.ipni.org/) as an alternative. The definition of alien status follows the definitions in Pyšek et al. (2004). For the preparation of Suppl. material 2, which includes the cultivated species of Montecristo, we refer to Plants of the World Online (POWO, 2024), as this appendix also includes species that are not treated in the Portal to the Flora of Italy 2024.2. The complete data sets collected for this study are available in Suppl. materials 1, 2.

Data analysis

The counts included species that had been previously reported, new reports, species that had not been found again, and species that were to be excluded. The species considered as cultivated exotics have been excluded from the analyses but are indicated in Suppl. material 2. A critical analysis of all the different sources of information was conducted. This analysis aimed to standardise their taxonomic and nomenclatural characteristics and to correct them where necessary based on the direct examination of critical findings. Species richness was expressed by the species-area relationship (SAR), based on the Arrhenius power function (D'Antraccoli et al. 2019). We used the best-performing constants of the Power function $S = c A^z$ (Arrhenius 1921), according to D'Antraccoli et al. (2024). The SAR was calculated for the whole flora and then separately for native

and alien species. The constants used for this function are c = 241.2 and z = 0.281 for the whole flora, c = 245.2 and z = 0.263 for native species, and c = 10.1 and z = 0.404 for alien species (D'Antraccoli et al. 2024). For each taxon included in the updated checklist, we recorded the following details: chorology, life form, historical and current occurrence, type of environment in which it was found, and frequency. To ascertain whether there was a significant association between two categorical variables, namely occurrence (historical or current), chorology (Pignatti et al. 2019), and life form (Pignatti et al. 2019), a χ^2 test of independence was applied. For analytical purposes, plant occurrences were classified into two main groups: confirmed species and species no longer found. To evaluate temporal trends across confirmed taxa and variation in the distribution of chorotypes, biological forms and families, a χ^2 test of independence was also applied. All analyses were performed with the software R (R RStudio 2023.12.1).

Results

A total of 584 vascular plant species resulted for Montecristo, of which 515 are spontaneous and 67 cultivated. Of the 515 spontaneous species, 14 are considered *excludendae*, therefore definitively excluded from the present flora of Montecristo, *Carex pendula* Huds., *Carpobrotus acinaciformis* (L.) L.Bolus, *Cneorum tricoccon* L., *Erica multiflora* L., *Erigeron canadensis* L., *Euphorbia dendroides* L., *Geranium robertianum* L., *Opuntia ficus-indica* (L.) Mill., *Oxalis violacea* L., *Polypogon maritimus* Willd. subsp. *maritimus*, *Saxifraga granulata* L. subsp. *granulata*, *Teucrium flavum* L., *Sedum hirsutum* All. subsp. *hirsutum*, and *Teucrium fruticans* L. subsp. *fruticans*.

The following calculation and analysis results have been obtained excluding the cultivated species and *excludendae*, therefore considering 501 species currently occurring on the island of Montecristo. During the exploratory visits carried out on Montecristo since 2000, 45 taxa new to Montecristo have been recorded and another 28 have been confirmed since their last record dates back to 1903 or 1864 (Table 1).

Among the newly recorded species, 9 (*Carex microcarpa* Bertol. ex Moris, *Erigeron canadensis* L., *Geranium purpureum* Vill, *Montia hallii* (A.Gray) Greene, *Opuntia monacantha* Haw., *Oxalis articulata* Savigny, *Polypogon subspathaceus* Req., *Saxifraga montis-christi* Mannocci, Ferretti, Mazzoncini & Viciani) resulted from the revision of the herbarium material, which led to the correction of previous erroneous identifications or even to the highlighting of the existence of new taxa. In the case of *Dactylis glomerata* L. the revision of herbarium specimen led to the identification of two subspecies: *D. glomerata* L. subsp. *glomerata*, and *D. glomerata* L. subsp. *hispanica* (Roth) Nyman. Besides, there have also been significant nomenclatural changes within the species already recorded, reflecting new knowledge, for example, the most frequent nomenclatural changes concern the attribution to a different genus, as in the case of *Calystegia soldanella* (L.) Roem. & Schult., *Aetheorhiza bulbosa* (L.) Cass., and *Hedysarum coronarium* L., which are now recognised as *Convolvulus soldanella* L., *Sonchus bulbosus* (L.) N.Kilian & Greuter subsp. *bulbosus*, and *Sulla coronaria* (L.) B.H.Choi & H.Ohashi, respectively.

Table 1. New vascular species identified on Montecristo Island since 2000. For each entry, the type of report (new or confirmed) is indicated, together with the status and date of publication.

Taxon	Type of report	Year of publication
Amaranthus deflexus L.	Confirmed, last record in 1903	2015
Anthoxanthum ovatum Lag.	New record	2018
Aphanes minutiflora (Azn.) Holub	New record	Unpublished
Astragalus pelecinus (L.) Barneby subsp. *pelecinus*	Confirmed, last record in 1903	2017
Austrocylindropuntia subulata (Muehlenpf.) Backeb.	New record	2014
Callitriche brutia Petagna	New record	2018
Callitriche stagnalis Scop.	New record	2018
Campsis radicans (L.) Bureau	New record	2014
Carduus pycnocephalus L.	Confirmed, last record in 1903	2013
Carex microcarpa Bertol. ex Moris	New record, previously attributed to *C. pendula*	2012
Catapodium pauciflorum (Merino) Brullo, Giusso, Miniss. & Spamp.	New record	Unpublished
Centaurea melitensis L.	Confirmed, last record in 1903	2014
Centaurium tenuiflorum (Hoffmanns. & Link) Fritsch	New record	Unpublished
Cerastium diffusum Pers. subsp. *diffusum*	New record	2014
Clematis vitalba L.	New record	2017
Convolvulus arvensis L.	New record	2017
Convolvulus siculus L.	New record	2017
Daucus carota subsp. *drepanensis* (Arcang.) Heywood	New record	Unpublished
Dactylis glomerata L. subsp. *glomerata*	New record, previously attributed to *D. glomerata*	Unpublished
Dactylis glomerata L. subsp. *hispanica* (Roth) Nyman	New record, previously attributed to *D. glomerata*	Unpublished
Equisetum ramosissimum Desf.	Confirmed, last record in 1903	2017
Erigeron bonariensis L.	New record, previously attributed to *E. canadensis*	2013
Erodium moschatum (L.) L'Hér.	Confirmed, last record in 1903	2015
Eryngium maritimum L.	Confirmed, last record in 1903	2014
Euphorbia maculata L.	New record	2023
Euphorbia prostrata Aiton	New record	2018
Euphorbia serpens Kunth	New record	2018
Galium scabrum L.	Confirmed, last record in 1903	2017
Geranium purpureum Vill.	New record, previously attributed to *G. robertianum*	2018
Herniaria hirsuta L. subsp. *hirsuta*	New record	2023
Hieracium racemosum Waldst. & Kit. ex Willd. subsp. *amideii* Gottschl., Gonnelli & Zoccola	New record	2019
Hypericum hircinum L.	Confirmed, last record in 1903	2012
Isoëtes durieui Bory	Confirmed, last record in 1903	2012
Juncus pygmaeus Rich. ex Thuill.	New record	2014
Lepidium didymum L.	New record	2011
Lolium multiflorum Lam.	New record	Unpublished
Lythrum hyssopifolia L.	Confirmed, last record in 1903	2015
Malva parviflora L.	Confirmed, last record in 1903	2018
Malva sylvestris L.	Confirmed, last record in 1903	Unpublished
Medicago minima (L.) L.	Confirmed, last record in 1903	2018
Neotinea maculata (Desf.) Stearn	New record	2014
Ophioglossum lusitanicum L.	Confirmed, last record in 1903	2014

Taxon	Type of report	Year of publication
Opuntia monacantha Haw.	New record, previously attributed to *O. ficus-indica*	2014
Osmunda regalis L.	Confirmed, last record in 1864	2012
Osyris alba L.	New record	2016
Oxalis articulata Savigny	New record, previously attributed to *O. violacea*	2014
Oxalis debilis Kunth	New record	2018
Oxalis dillenii Jacq.	New record	2018
Phelipanche ramosa (L.) Pomel	New record	2019
Phoenix canariensis H.Wildpret	New record	Unpublished
Poa annua L.	Confirmed, last record in 1903	2018
Poa bulbosa L.	Confirmed, last record in 1903	2014
Polygonum maritimum L.	Confirmed, last record in 1903	2017
Polypogon subspathaceus Req.	New record, previously attributed to *P. maritimus*	2018
Polypogon viridis (Gouan) Breistr. subsp. viridis	Confirmed, last record in 1903	2018
Potentilla reptans L.	Confirmed, last record in 1903	2017
Rhagadiolus stellatus (L.) Gaertn.	Confirmed, last record in 1903	2017
Romulea columnae Sebast. & Mauri	Confirmed, last record in 1903	2013
Rostraria cristata (L.) Tzvelev	Confirmed, last record in 1903	2013
Salsola tragus L.	New record, previously attributed to *S. kali*	2018
Saxifraga montis-christi Mannocci, Ferretti, Mazzoncini & Viciani	New record, previously attributed to *S. granulata*	2016
Serapias vomeracea (Burm.f.) Briq.	New record	2014
Silybum marianum (L.) Gaertn.	New record	2017
Solanum lycopersicum L.	New record	2015
Trifolium scabrum L.	Confirmed, last record in 1903	2018
Trifolium tomentosum L.	Confirmed, last record in 1903	2018
Trigonella smallii Coulot & Rabaute	Confirmed, last record in 1903	2018
Triticum turgidum L. subsp. *durum* (Desf.) Husn.	New record	2018
Urtica atrovirens Req. ex Loisel.	New record	2013
Urtica membranacea Poir.	New record	2015
Valerianella microcarpa Loisel.	New record	2015
Viburnum tinus L. subsp. *tinus*	Confirmed, last record in 1903	Unpublished
Vicia faba L.	New record	Unpublished

According to the SAR formula, overall, we obtained +7.6% taxa compared to the expected value of 465 considering the total of spontaneous and non-cultivated species. Moreover, for native species, we obtained +3.56% taxa compared to the expected value of 453. We obtained +19.21% taxa for alien species compared to the expected value of 26. Among taxa of Montecristo, life forms are not equally distributed ($p < 0.001$). Results show that the predominant form is the therophytes, which account for 54.2% of the total, with 273 taxa. All results are presented in Fig. 1.

Chorotypes are also not equally distributed ($p < 0.001$) and analysis revealed that the major geographical distributional elements are represented by 36.9% of Eurosiberian-Mediterranean and 31.2% of Mediterranean species. All results are presented in Fig. 2.

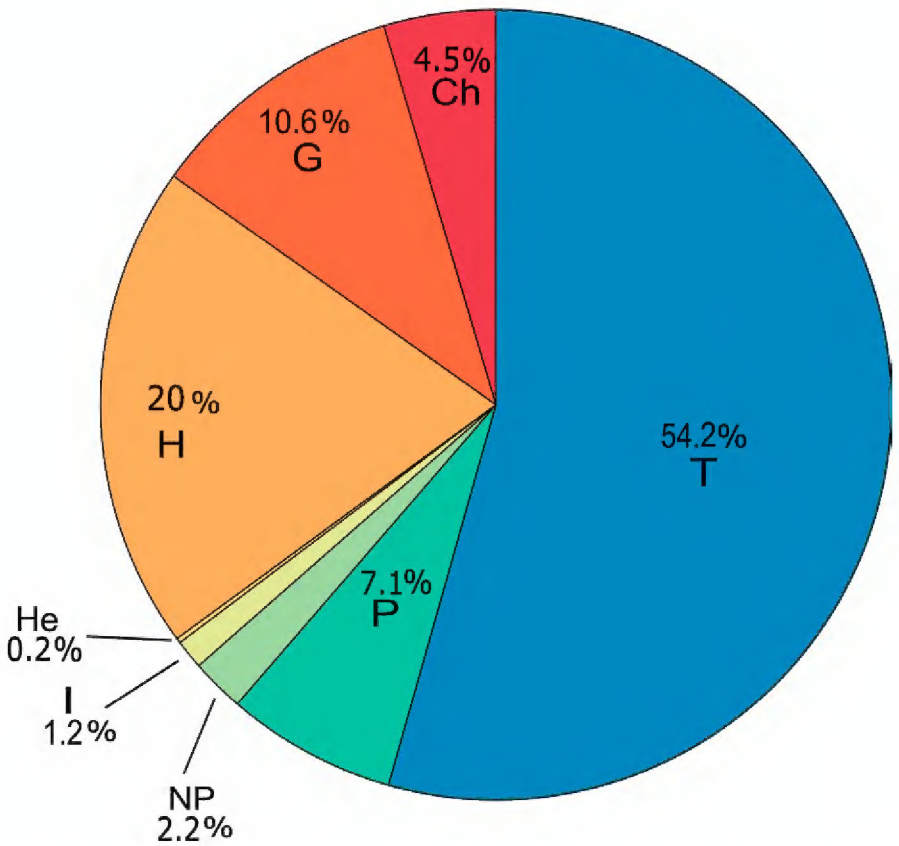

Figure 1. Percentage of life forms of spontaneous vascular species on Montecristo Island. Life form legend: Ch = Chamaephytes, G = Geophytes, H = Hemicryptophytes, He = Helophytes, I = Hydrophytes, NP = Nanophanerophytes, P = Phanerophytes, T = Therophytes.

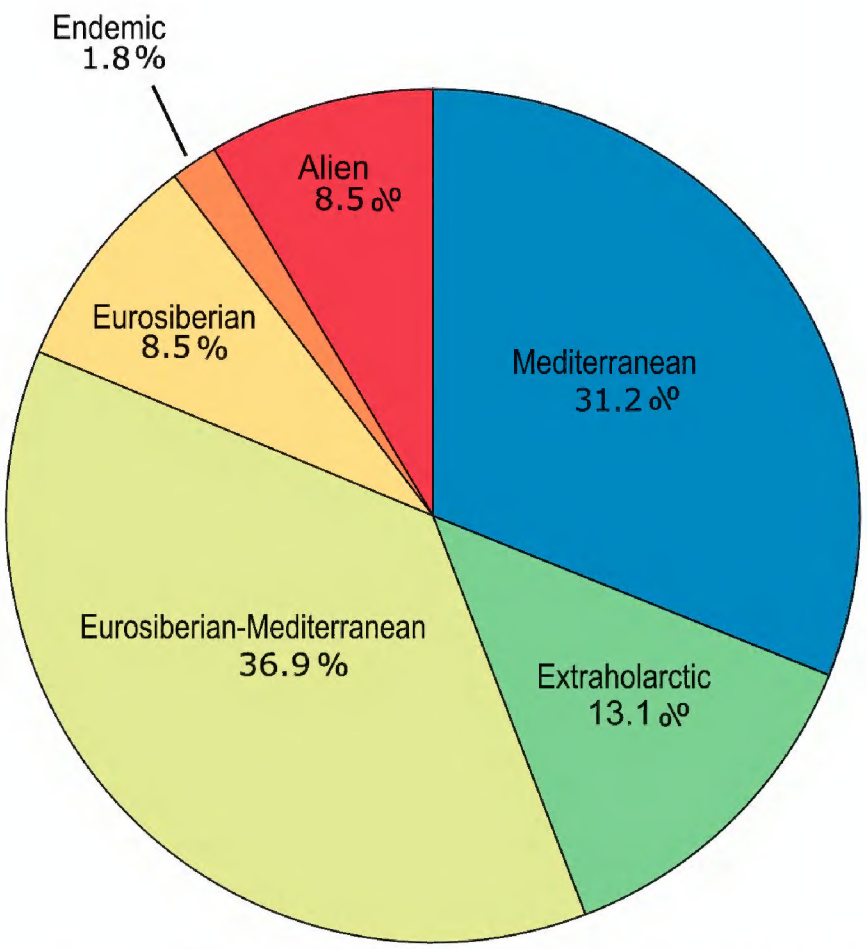

Figure 2. Percentage of chorotypes of spontaneous vascular species on Montecristo Island. Legend of chorological types: Alien = alien species; Endemic: Italian endemic; Eurosiberian: species showing range within the Eurosiberian floristic region; Eurosiberian-Mediterranean: species showing range across Eurosiberian and Mediterranean floristic regions; Extraholartic: species showing range larger than Holarctic floristic kingdom; Mediterranean: species showing range within the Mediterranean floristic region.

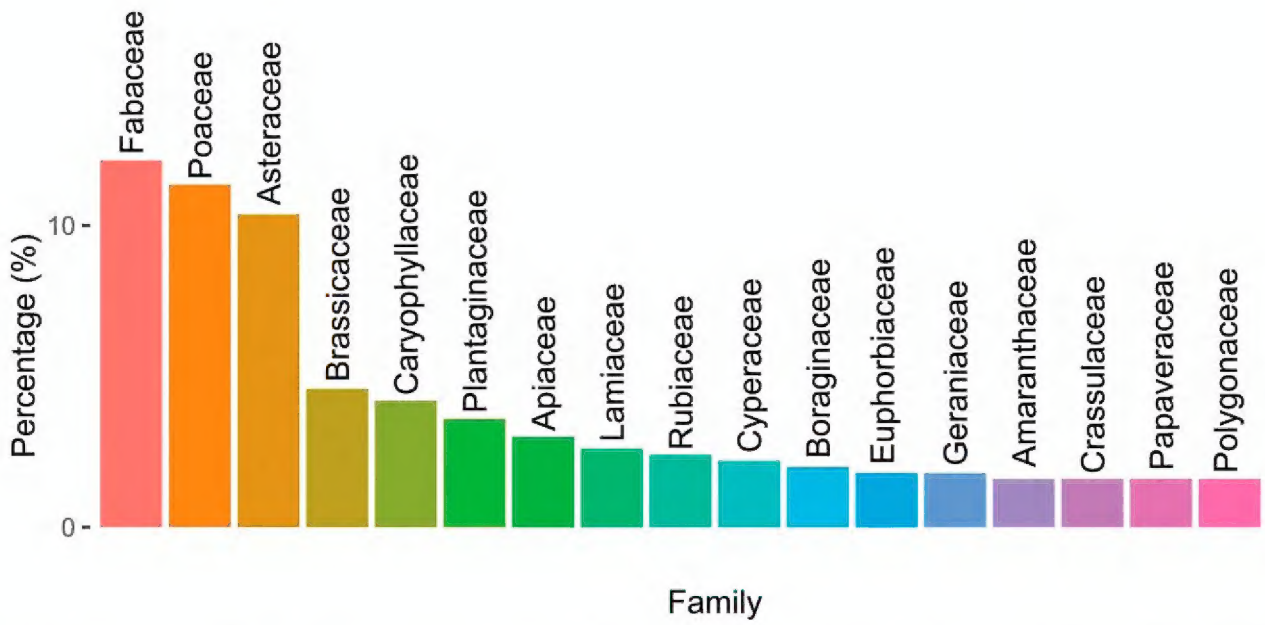

Figure 3. Percentage of the 17 most common families on Montecristo Island, representing 60% of the total. Only families containing eight or more genera present on the island of Montecristo and individually accounting for more than 1.5% of the total are included.

We found that also families are not equally distributed ($p < 0.001$), where Fabaceae (12.15%), Poaceae (11.35%), and Asteraceae (10.36%) are the most abundant (Fig. 3). Families are significantly associated with life forms ($p < 0.001$), Fabaceae, Poaceae and Asteraceae are mostly represented by therophytes and then hemicryptophytes.

Life forms are significantly associated ($p < 0.001$), with chorotypes: Mediterranean and Eurosiberian-Mediterranean taxa are mostly represented by therophytes (53% and 62% respectively). Italian endemics are mostly hemicryptophytes (44%) and chamaephytes (33%), while alien taxa are mostly represented by therophytes, phanerophytes and geophytes (more than 85% altogether).

Italian endemics (as defined by Peruzzi et al. 2014a), collectively account for 1.8% of the total. Details are summarised in Table 2.

Alien taxa account for 8.53% of the total, counting 30 spontaneous species. 22 species are listed in the checklist of the alien flora of the Tuscan Archipelago (Lazzaro et al. 2013), two units (*Conringia orientalis* (L.) Andrz. ex DC. and *Vicia lens* (L.) Coss. & Germ.) were no longer found since the first report in 1903 and 1957 respectively, and seven species are new reports from 2012 to 2023. A full list of these species is provided in Suppl. material 1. Temporal analysis was performed looking for correlations and variations in the distribution of chorological types, biological forms and families of species over time. Results show that only alien species varied significantly, increasing over time ($p < 0.001$).

Discussion

The earliest known botanical information on Montecristo dates back to 1832, when Giuseppe Giuli conducted a brief excursion on the island and subsequently used the data he collected to supplement Antonio Bertoloni's Flora Italica (1837–1854) (Paoli and

Table 2. List of taxa endemic and subendemic to Montecristo Island. For each taxon, its phytogeographic importance and its distribution in Tuscany and the Tuscan Archipelago are indicated.

Species	Phytogeographic relevance	Distribution in Tuscany and the Tuscan Archipelago
Carduus fasciculiflorus Viv.	Corsican Sardinian domain	Occurring in Tuscany only in Montecristo, where it is relatively abundant
Carex microcarpa Bertol. ex Moris		Occurring in Tuscany only in the Tuscan Archipelago: in Montecristo Elba, and Capraia, in the past also reported in Giglio where it has not recently been found
Hypericum hircinum L. subsp. *hircinum*		Occurring in Tuscany only in the Tuscan Archipelago: in Montecristo and Elba
Scrophularia trifoliata L.		Occurring in Tuscany only in the Tuscan Archipelago: in Montecristo and Gorgona
Verbascum conocarpum Moris subsp. *conocarpum*		Occurring in Tuscany only in the Tuscan Archipelago: in Montecristo and Elba
Limonium sommierianum (Fiori) Arrigoni	Endemic to the Tuscan Archipelago	Occurring in Giannutri, Giglio and Montecristo
Linaria capraria Moris & De Not.		Occurring in Capraia, Giglio, Elba, Pianosa and Montecristo. The presence in Gorgona is doubtful
Mentha requienii Benth. subsp. *bistaminata* Mannocci & Falconcini		Occurring in Capraia and Montecristo
Saxifraga montis-christi Mannocci, Ferretti, Mazzoncini & Viciani	Endemic to Montecristo	Occurring only in Montecristo
Hieracium racemosum Waldst. & Kit. ex Willd. subsp. amideii Gottschl., Gonnelli & Zoccola		Occurring only in Montecristo

Romagnoli 1976). The first list of vascular plants compiled for the island of Montecristo, comprising 343 species, was produced by Caruel (1864). In Sommier (1902, 1903), Montecristo was documented to have 406 described species. A subsequent list of vascular plants dedicated to Montecristo was published by Paoli and Romagnoli (1976). This list described 471 units, excluding the species cultivated around the habitation area of Cala Maestra. Subsequent additions to this list were published by Sartori (1978), resulting in 489 species. A total of 582 species were counted in this work, of which 501 are considered as spontaneous vascular plants of Montecristo's flora, obtained from a synthesis of bibliographic sources with directly verified observations, but excluding cultivated taxa and species considered as *excludenda*. Notably, five species excluded from this checklist (*Cneorum tricoccon*, *Erica multiflora*, *Euphorbia dendroides*, *Teucrium flavum* and *Teucrium fruticans*) were previously reported by Giuli (1833), however, they probably are the result of labelling or identification errors as they are all characterised by a preference for calcareous habitats, which is an unlikely scenario on an island that is almost exclusively granitic. On the other hand, *Carpobrotus acinaciformis* was excluded from the floristic list because it is no longer present after its eradication in 2014 (Sposimo et al. 2014). Regarding the new report for the island, it is worth noting the case of *Saxifraga granulata* L., a species recently excluded from the flora of Montecristo and replaced by the *Saxifraga montis-christi* (Mannocci et al. 2016). Additionally, *Geranium purpureum* was observed during a vegetation survey conducted in 2005, following a period during which it had not

been recorded in previous works. The *exsiccata* preserved in the Herbarium of Florence were therefore studied together with those of a related species, *Geranium robertianum*. Through this process, it was concluded that all the specimens previously attributed to *G. robertianum* were, in fact, *G. purpureum* (Peruzzi et al. 2018). Lastly, some names have also been re-evaluated based on nomenclatural priority. An example of a name change is *Sagina subulata* (Sw.) C.Presl, which is now known as *Sagina hawaiensis* Pax.

A comparison of Montecristo with the floras of the Tuscan Archipelago reveals that, in terms of the number of species per km^2, Montecristo shares the lowest species number with Giannutri (Carta et al. 2018), although the decrease in floristic diversity on Montecristo is more drastic than on other islands and cannot be justified based on its size alone (Arrigoni et al. 2003). However, it should be noted that according to a SAR approach (D'Antraccoli et al. 2024), we recorded a slightly higher number of species than expected. Further factors are therefore required to explain this phenomenon. Montecristo is the most distant of the islands from the mainland coast, situated approximately 63 km away from mainland Tuscany. It is the least studied from a botanical perspective due to its remote location and distinctive morphological characteristics, which have hindered exploration over time. Additionally, there are areas within the island that are inaccessible, and for which floristic data are scarce. Also, the substrate is characterised by homogeneity, with the vast majority of the island's terrain comprising granite (Innocenti et al. 1997). This geological composition gives rise to soil layers of a siliceous nature that prove limiting for obligate chalcophiles. It seems reasonable to suggest that a further limitation to the floristic development of the island is probably due to the considerable biological imbalance that has occurred on the island as a result of the increase in the alien faunal component (goats and mice) and the expansion of the invasive plant species *Ailanthus altissima* (Mill.) Swingle. Further targeted studies would be required to confirm this hypothesis and assess the impact of the fauna component on the island's vegetation. Nevertheless, following the eradication of black rat *Rattus rattus* Linnaeus, 1758 by the LIFE Project 'Montecristo 2010', there have been no further sightings. However, the goat population is of historic interest and therefore protected, it has become evident that the presence of these feral goats is having a significant negative impact on the island ecosystem, due to overgrazing which causes soil damage, a lack of vegetation renewal, ecosystem degradation and biodiversity loss. From a chorological perspective, it is notable that Montecristo, as well as Gorgona and Capraia (Carta et al. 2018), exhibit a floristic affinity with the Cyrno-Sardinian territories. The islands of the Tuscan Archipelago exhibit a prevalence of species with a broad distribution, either Mediterranean-tetidic or with a broader distribution, holarctic, yet still tetidic in their gravitation (Euro-Mediterranean or Euro-tetidic) (Arrigoni et al. 2003), Montecristo does not differ in this general feature from the others. It is worth noting that Montecristo shares the prevalence of southern holarctic species with Elba and Gorgona, indicating a lower prevalence of the Mediterranean component compared to the continental one (Carta et al. 2018). However, there is a lower presence of the total holarctic component in Montecristo compared to Elba. This can be explained by the lesser isolation of Elba and the greater impact of European flora migrations during glacial periods (Carta et al. 2018). Additionally, Montecristo's lower altimetric development reduces the possibility of maintaining a meso-thermophile or mesophile flora. The

percentage of Italian endemic species in the Archipelago is not high when compared with the other Mediterranean islands, but it is nevertheless higher in Montecristo than in all the other neighbouring islands considering their area (Foggi et al. 2015). Conversely, biological invasions, in conjunction with socio-cultural changes, represent a significant contributing factor to the decline in endemism (Foggi et al. 2015) and constitute a substantial threat to biodiversity, particularly in island ecosystems (Médail 2013). Isolated ecosystems are more susceptible to increased invasion rates (Hulme et al. 2007; Lazzaro et al. 2014). However, Montecristo could represent a notable exception due to its strict conservation regime and the absence of significant tourism and land exploitation over the past four decades. Nevertheless, alien species were the only chorological type to demonstrate a notable increase over time. This suggests that even comprehensive protection and limited and controlled tourist exploitation are insufficient to render a small, isolated island immune to the pressures of anthropogenic disturbance. These pressures, together with socio-cultural changes in land use and climate change, are the main factors driving plant invasions (Hobbs, 2000), which, together with the detrimental effects of goats on the island, are leading to a degraded state of the island's vegetation.

Our research was based on a revision of available herbaria and bibliographic materials. However, some taxa or systematic groups would benefit from further investigation. Further morphological and cariological investigations would be required to provide stronger evidence for the presence of *Sedum dasyphyllum* L. subsp. *glandulifer*um (Guss.) Nyman (see Suppl. material 1), as previously indicated by Giuliani et al. (2014). Another taxon that requires further attention is *Plantago weldenii* Rchb., which is currently reported for the island of Montecristo. However, its taxonomic identity should be investigated more thoroughly, given the complexity of the group (Höpke et al. 2019; Lazzaro et al. 2020). Additionally, based on observations made by Vincenzo Gonnelli (pers. comm.), it appears that some of *Quercus ilex* samples collected from Montecristo individuals may display identification elements consistent with *Q. ilex* subsp. *rotundifolia* (Lam.) T.Morais., a commonly occurring subspecies in the Iberian Peninsula (under the name *Q. ilex* subsp. *ballota* (Desf.) Samp. in Castroviejo et al. 1990; see also Ferrer-Galego and Saez 2019 for nomenclatural issues on this taxon).

Conclusion

This study allowed the creation of an updated inventory of Montecristo Island, an important biodiversity hotspot for the Tuscan Archipelago and the Mediterranean in general. This inventory highlights the need for appropriate conservation measures in this region. Since the establishment of the integral reserve managed by CUFAA in 1971 and the following inclusion in the National Park of the Tuscan Archipelago in 1991, a considerable number of conservation activities have been conducted, both in situ and ex-situ, in addition to comprehensive studies designed to enhance comprehension of the archipelago's floristic richness and evaluate prospective conservation strategies. This revised account of the vascular, spontaneous, and cultivated flora of Montecristo Island serves as a significant reference for the development of knowledge regarding the island and the promotion of its protection.

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Supplementary material 1

Updated inventory of the vascular flora of the Island of Montecristo

Authors: Eugenia Siccardi, Giulio Ferretti, Bruno Foggi, Michele Mugnai, Maria Rosaria Pasqualina Bardaro, Marco Landi, Giovanni Quilghini, Antonio Zoccola, Lorenzo Lazzaro

Data type: docx

Explanation note: Inventory of spontaneous vascular flora.

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Supplementary material 2

List of cultivated exotics taxa found on Montecristo Island

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Data type: docx

Explanation note: List of cultivated exotics taxa.

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